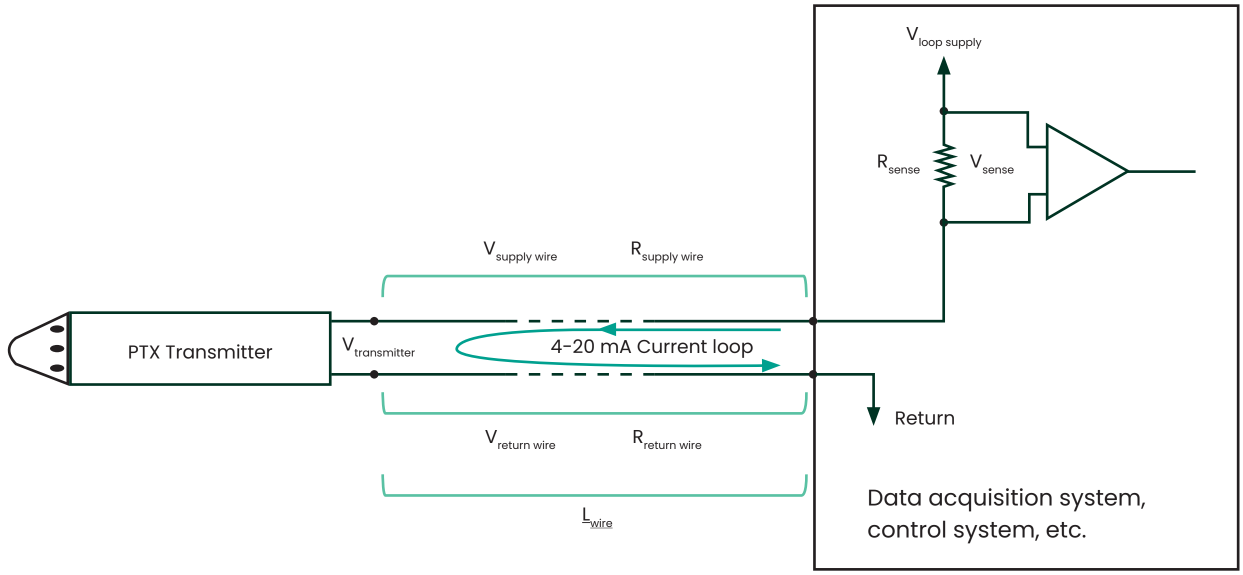
Druck
a Baker Hughes business

Tech tip

Why doesn't my pressure transmitter read full scale?

Sensor signals in the form of a 4 to 20mA current loop are commonplace in industrial systems. Devices using this form of signal output are referred to as transmitters. The current loop signal has the advantages of noise immunity, very long cable lengths, and only two wire connectivity. If all of the factors for a loop transmitter system are not taken into account, the system may not function or have limited functionality. This note describes the how to calculate the system requirements and limitations.

The system of a pressure transmitter and a host system (e.g. data acquisition system, control system, etc.) is modeled below.



$V_{transmitter}$ - The voltage the transmitter sees

$R_{supply\ wire}$ - The resistance of the supply wire

$V_{supply\ wire}$ - The voltage drop across the length of supply wire

$V_{return\ wire}$ - The resistance of the supply wire

L_{wire} - The length of cable connecting the transmitter to the DAQ/control system

$V_{loop\ supply}$ - The current loop supply voltage

R_{sense} - The loop current sense resistance (inside DAQ/control equipment)

V_{sense} - The voltage drop across the sense resistor

Long cable lengths or a low V_{supply} voltage can cause the voltage at the transmitter, $V_{transmitter}$, to be lower than required for the transmitter to operate. Knowledge of the data acquisition system and its sense resistance and loop supply voltage is imperative. The voltage at the transmitter is:

$V_{transmitter} = V_{loop\ supply} - V_{sense} - V_{supply\ wire} - V_{return\ wire}$

We assume the supply wire and the return wire are the same length and the same gauge. This makes $R_{supply\ wire} = R_{return\ wire}$ (we can call this R_{wire}). Being a current loop, they both experience the same current. So by Ohm's law, V=I*R, they both have the same voltage drop,

$V_{supply\ wire} = V_{return\ wire}$ (we can call this V_{wire}).

We can simplify the transmitter voltage equation to:

$V_{transmitter} = V_{loop\ supply} - V_{sense} - 2 * V_{wire}$.

Again, using Ohm's law, the voltage drop across a length of wire is directly proportional to current and the resistance. The worst case voltage drop will be when the transmitters output is at its highest, 20mA. For ease of calculation, we express this in amps, 0.020A. The voltage drop across the sense resistor is $V_{sense} = 0.020A * R_{sense}$. The voltage at the transmitter can be calculated by:

$V_{transmitter} = V_{loop\ supply} - (0.020A * R_{sense}) - 2 * (0.020A * R_{wire})$

The resistance of the wire will depend on its construction, material, gauge, and length. It is generally expressed as a resistance per unit length, e.g. Ω/ft or Ω/m. For most Druck cabled transmitters, the wire is 24AWG, made up of seven strands of 0.2mm tinned copper wire. This has a resistance of 0.0235Ω/ft or 0.0764Ω/m. Historically DAQ or control systems, the sense resistance is 250Ω. More modern systems use a lower resistance to measure the current, say 100Ω. We can plug this into the equation above and simplify:

$V_{transmitter} = V_{loop\ supply} - (0.020A * 250\Omega) - 2 * (0.020A * 0.0235\Omega/ft * L_{wire-ft})$ length in feet

$V_{transmitter} = V_{loop\ supply} - 5V - 0.00094\ V/ft * L_{wire-ft}$

(in meters, $= V_{loop\ supply} - 5V - 0.00306\ V/m * L_{wire-m}$)

For Druck depth transmitters, e.g. PTX1830, the minimum operating voltage is 9V. This means that the loop supply voltage must be greater than 14V (9V + 5V for the sense resistor) by $0.00094V/ft * L_{wire-ft}$. In other words, for every 1000ft of cable, the $V_{loop\ supply}$ needs to be 0.94V greater than 14V.

For a PTX1830 with a loop supply of 12V, a 250Ω sense resistor, and no cable, the highest the system could read is 50% FS (12ma). This is obviously a problem. The V_{loop} supply would have to be at least 14V and that would still not allow for any length of cable. With a more modern 100Ω sense resistor and a V_{loop} supply of 12V, it would achieve 100% full scale but there would be a cable length limitation of 532ft.

For wire other than what is provided with a transmitter, the resistance can be found below.

AWG	Cross sect. mm^2	Metric stranding	Resistance Ω /km
26	0.128	1/0.4, 7/0.15, 19/0.1	146
25	0.163	14/0.12	110
24	0.22	1/0.5, 7/0.2, 19/0.12, 30/0.1	76.4
23	0.25	1/0.6, 14/0.15, 32/0.1	70.1
22	0.32	7/0.25, 19/0.15, 30/0.12	54.8
21	0.41	13/0.2, 55/0.1	44
20	0.52	16/0.2, 44/0.12	34.5
18	0.75	19/0.25, 24/0.2, 96/0.1	23